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APL Integrated Multi-warfare Simulation (AIMS)
Considering Resource Conflict Resolution and Warfare Area Inter-dependencies in Multi-Warfare Analyses

Dr. Joseph G. Kovalchik

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National Security Analysis Department

- **Problem Addressed**
- **Proposed Solution**
- **Simulation Federation Development**
- **Simulation Federation Execution**
- **Future Work**
- **Summary**

The Need

- **There is an emerging need for analysis to be performed at the "multi-warfare" level, motivated by**
  - **Transition to "capabilities-based" acquisition**
  - **Creation of multi-mission structures (e.g., Sea Shield)**
  - **Need to assess performance/effectiveness of multi-mission platforms (e.g., DD(X))**
- **Integrated multi-warfare analyses have been difficult to conduct in the past**
  - **No one model can be easily used to faithfully replicate the detailed warfare area treatments found in specialized mission-level simulations (e.g., AAW, ASW, SUW, MIW, etc.)**
  - **When a series of "stove-piped" models are used independently (to do each of the warfare area analyses) for a common scenario, it is difficult to "integrate" the results, i.e.,**
    - **By off-line methods**
    - **By "sneaker net" approaches**

Observations

- **There is a gap in the analysis modeling and simulation toolset**
  - **Previous efforts to conduct multi-warfare analyses have been conducted on carefully constructed scenarios, which has led to artificially stove-piped, single-mission-area analyses**
  - ***These studies have avoided both the effects of competing resources across multi-warfare areas and the dependencies of one warfare area on another***
  - **Campaign-level simulations tend to lack sufficient fidelity to answer specific multi-warfare questions**
  - **"Simulations of choice" of analysts in individual mission areas do not represent other mission areas adequately for use in multi-mission analyses**

Agenda

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- **Create a tool to support analysis at a new "multi-warfare" level in the traditional military analysis simulation pyramid**
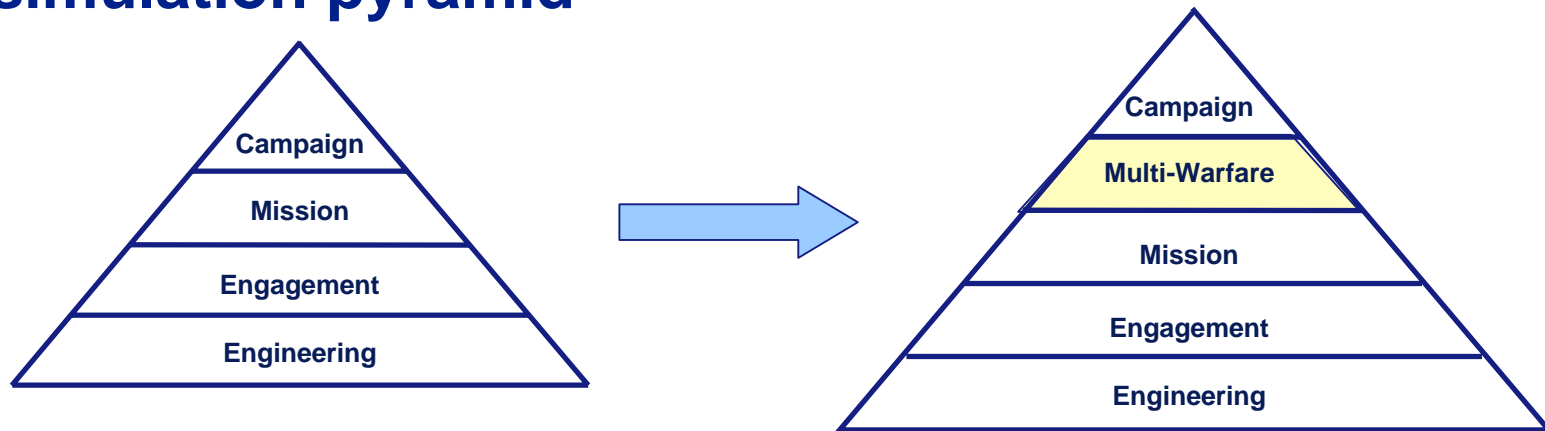
- **The enablers:**
  - **Continuing advances in computer processing speed (Moore's law) and networks**
  - **An interoperable simulation standard (the High Level Architecture)**

Solution Requirements

- **Develop the APL Integrated Multi-warfare Simulation (AIMS), which provides the means to conduct analysis on the execution of integrated warfare in multiple mission areas**

- **AIMS should provide the capability to**
  - **Incorporate simulations of choice based on the analysis task at hand**
  - **Consider the effects of competing resources across multi-warfare areas and the dependencies of one warfare area on another**
  - **Provide a Single Point of Entry (SPE) for scenario data**
  - **Coordinate the execution of scenario runs and data collection**
  - **Visualize the scenario interactions, and**
  - **Assist in post-run analysis**

FY05 AIMS Federation Structure

Maritime Component Commander

Commander Federate

Component Commanders

USWC	MIWC	SUWC	ADC	Other

Alignment w/Simulations in Federation

USWC BFEM	MIWC BFEM	SUWC ORBIS	ADC SAMS For AAW	ADC EADSIM For BMD	Other NSS

Platform Commanders

*	*	*	*	*	*
Platform A CDR	Platform B CDR	Platform C CDR	Platform D CDR	Platform E CDR	Platform F CDR

...
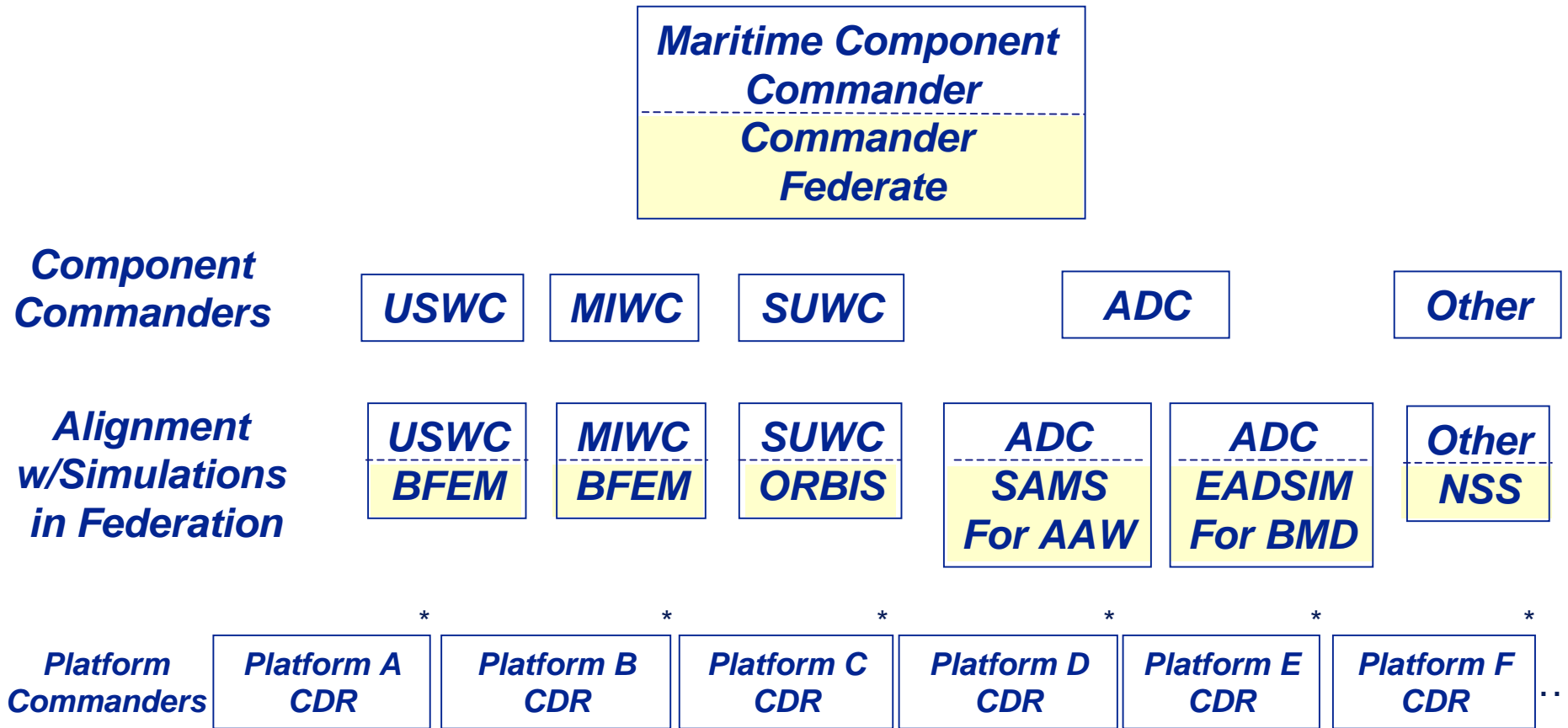
*Simulation in federation that is "controlling" a particular platform will change, e.g., as mission priorities change due to events; this is accomplished by "transfer of ownership" from one simulation to another

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- **Battle Force Engagement Model (BFEM) was selected to simulate the ASW warfare area**
  - **BFEM is a Monte Carlo simulation (C code) of Undersea Warfare (USW) engagements for both mine warfare (MIW) and ASW**
  - **models the tactics, kinematics and performance of submarines, surface combatants, ASW aircraft, mines and individual offboard sensors**

- **Extended Air Defense Simulation (EADSIM) was chosen to assess the effectiveness of Ballistic Missile Defense (BMD)**
  - **It provides a many-on-many theater-level simulation of air and missile defense, an integrated simulation tool (C++) to support joint and combined force operations**

- **Naval Simulation System (NSS) was selected to model various functions not adequately addressed by specialized combat models**
  - **NSS is a multi-sided, multi-warfare, object-oriented, Monte Carlo maritime simulation (C++) intended primarily for use by the analysis community in support of concept assessments and system effectiveness studies**

- **Orbis was selected to model the SUW mission area.**
  - **Orbis is a multi-sided, object-oriented (Java), Monte Carlo simulation intended for a variety of maritime applications including defending against small-boat attacks**
- **Surface AAW Multi-ship Simulation (SAMS) was selected to simulate the shipboard defenses against anti-ship cruise missiles**
  - **SAMS is a Monte Carlo event driven air defense system simulation (GPSS/H code) designed to evaluate multi-ship effectiveness. It utilizes results from high-fidelity models that provide performance data at the combat system level for sensors and weapons**
- **Commander Federate**
  - **Expert-system federate used to resolve resource allocation conflicts among warfare areas**

APL Integrated Multi-warfare Simulation (AIMS)

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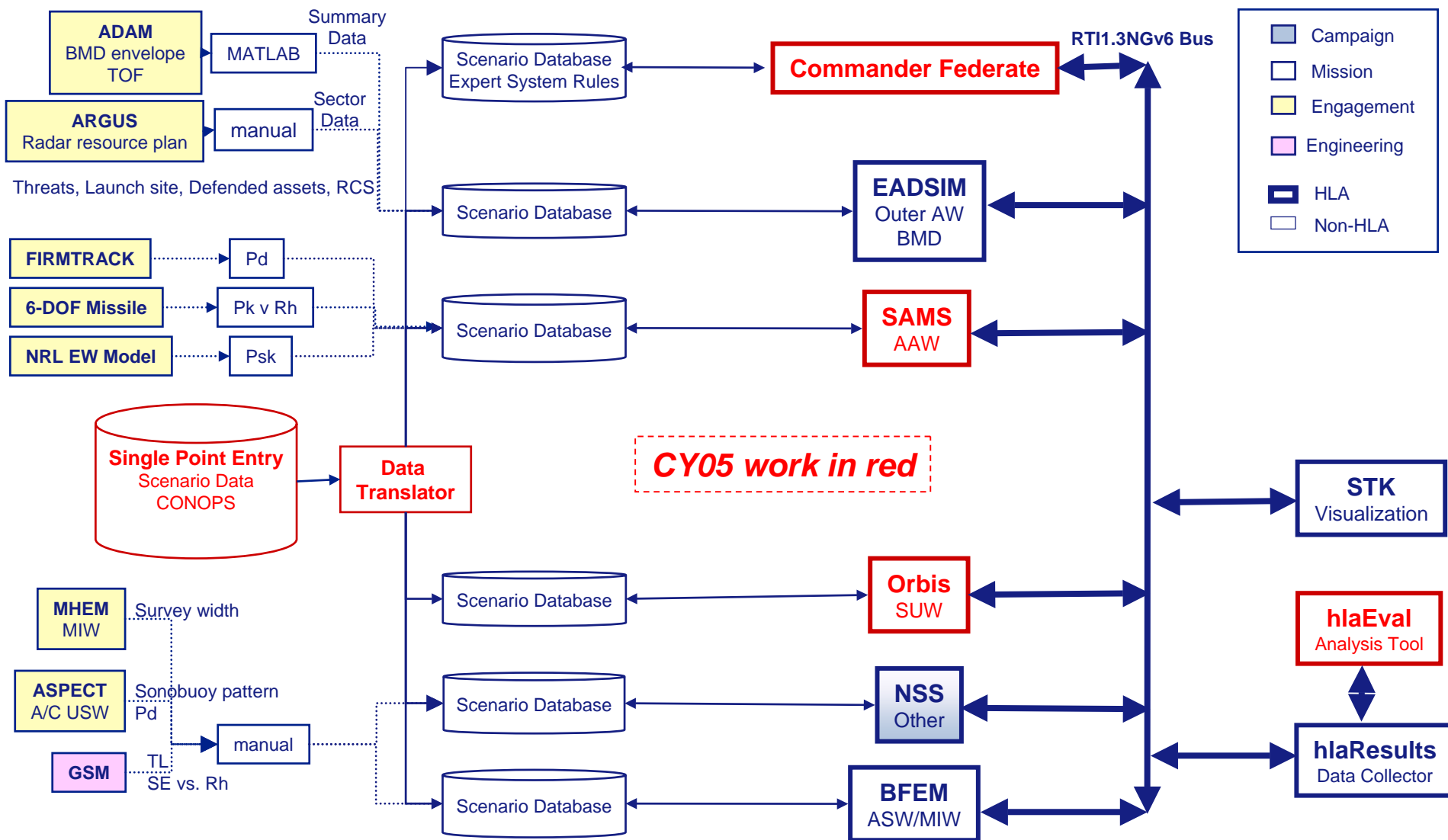
National Security Analysis Department
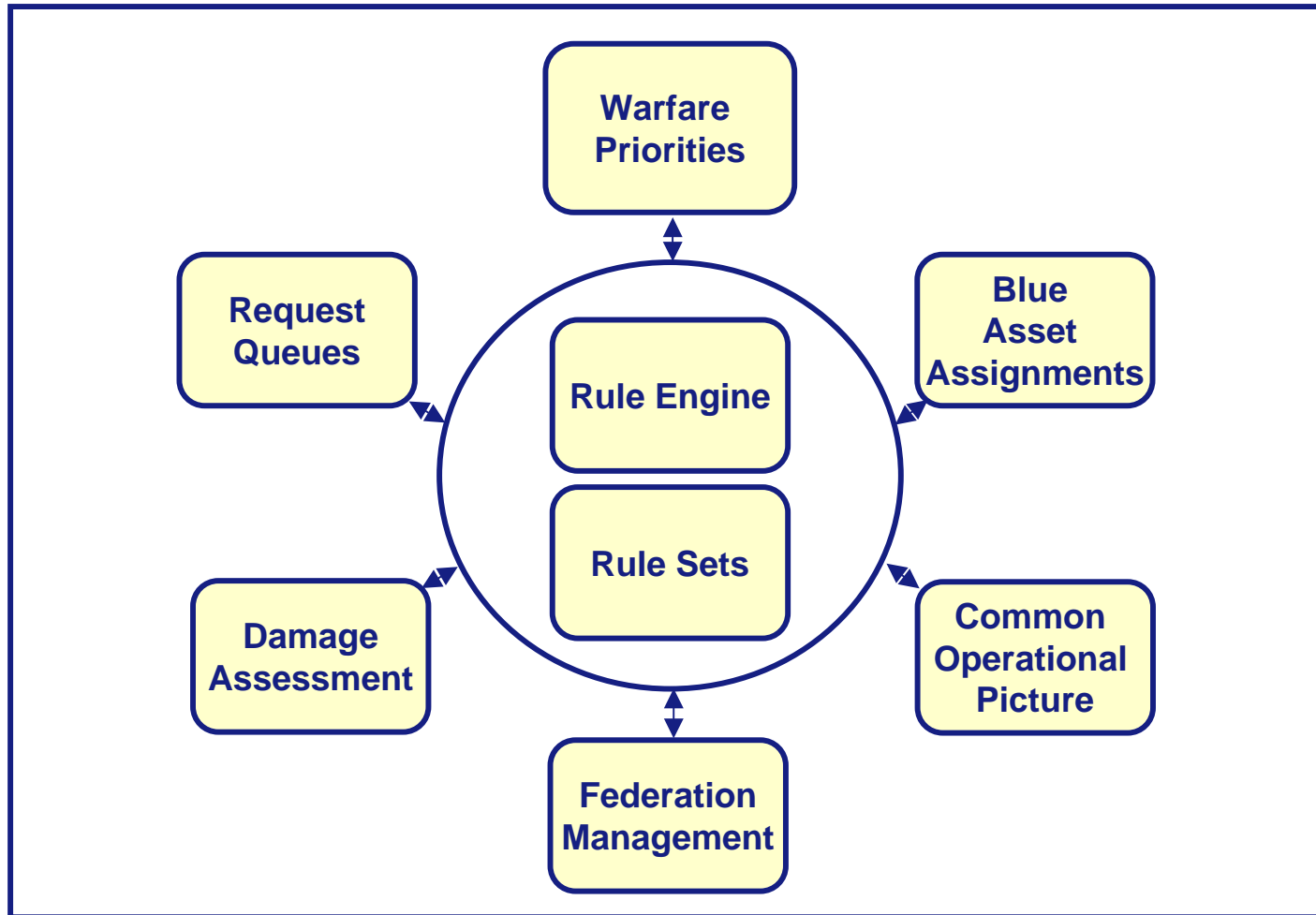
Commander Federate

Commander Federate Tasks

- **Set warfare priorities**
  - **By time and/or event**

- **Provide conflict resolution on asset allocation**
  - **Allocate a multi-warfare capable platform to a warfare area when conflicts arise**

- **Provide conflict resolution on motion plans**
  - **General force motion**
  - **Motion plans to optimize sensors**
  - **Water/air management assignments**

To be discussed in Future Work

- **Provide conflict resolution on weapon utilization**
  - **Allocate a weapon system to a warfare area when conflicts arise**
- **Provide conflict resolution on sensors utilization**
  - **Allocate a sensor system to a warfare area when conflicts arise**

- **Commander federate uses event triggers to expose Commander's intent to Combat Models (CMs)**

- **Triggering events are associated with timeouts at which time the next highest triggered priority is assigned**

- **Contact reports give an indication of threats**
  - **Distance, accuracy, classification**

Event Triggers
Contact Reports
Weapon Fires
Weapon Hits
Blue Casualties
Geographic Events

Decision Rules
ROE State
Timeouts
COP
Engagement Data
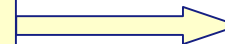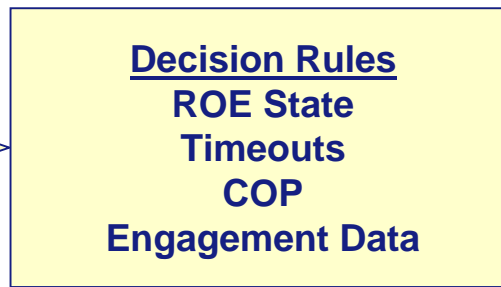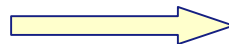
Commander's Intent

Asset Requests
Commander Federate

- **Commander federate uses Asset Requests from CMs to address resource allocations**

- **Asset Requests include:**
  - **Mission Area, Reason, Urgency, Earliest Start, Latest Start, Duration, Class Type Requested**
  - **Requests can be withdrawn any time prior to reassignment**

- **Readiness reports provide the means to communicate mission status and equipment configuration**

Event Triggers
Asset Request
Readiness Reports
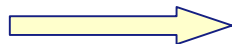
Decision Rules
ROE State
Warfare Priorities
Minimum Assignments
Damage Assessments
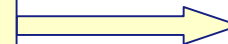
Asset Transfer
(Grant/Pending/Denied)

- **Assets are chosen from lowest to highest warfare priority area**
  - **If an asset is available and can meet time on datum (transit and reconfiguration) then a grant is sent to gaining and loosing CM that sets in motion the following sequence**

- **Commander federate uses Maneuver Requests from CMs to address changes to Commander-imposed constraints**

- **Maneuver Requests include those for:**
  - **Moving/fixed area assignments**
  - **Course/speed directives**
  - **Independent operations**
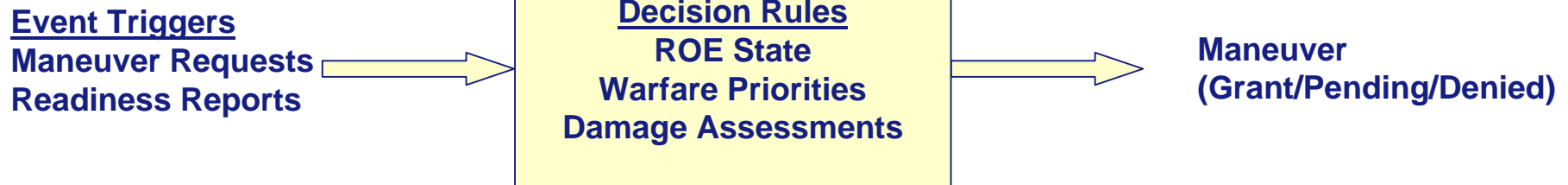
Event Triggers
Maneuver Requests
Readiness Reports

→

Decision Rules
ROE State
Warfare Priorities
Damage Assessments

→

Maneuver
(Grant/Pending/Denied)

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- **Commander Federate enables blue damage assessments from red weapons**

Event Triggers
Weapon Hits
Readiness Reports

Decision Rules
Damage Tables
Damage Accumulation
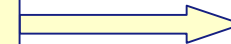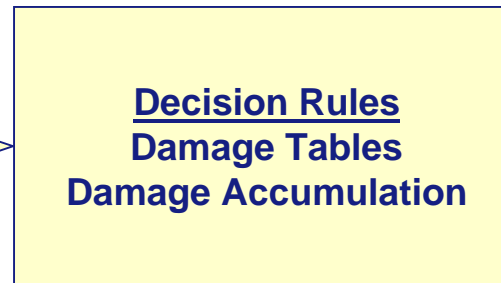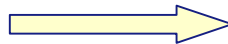
Damage Assessments

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Executing Multiple Federations

- **Execution is coordinated through a combination of Remote Method Invocation Servers (or APL Distributed Scheduler) and the use of synchronization points**
- **Multiple federations run concurrently**
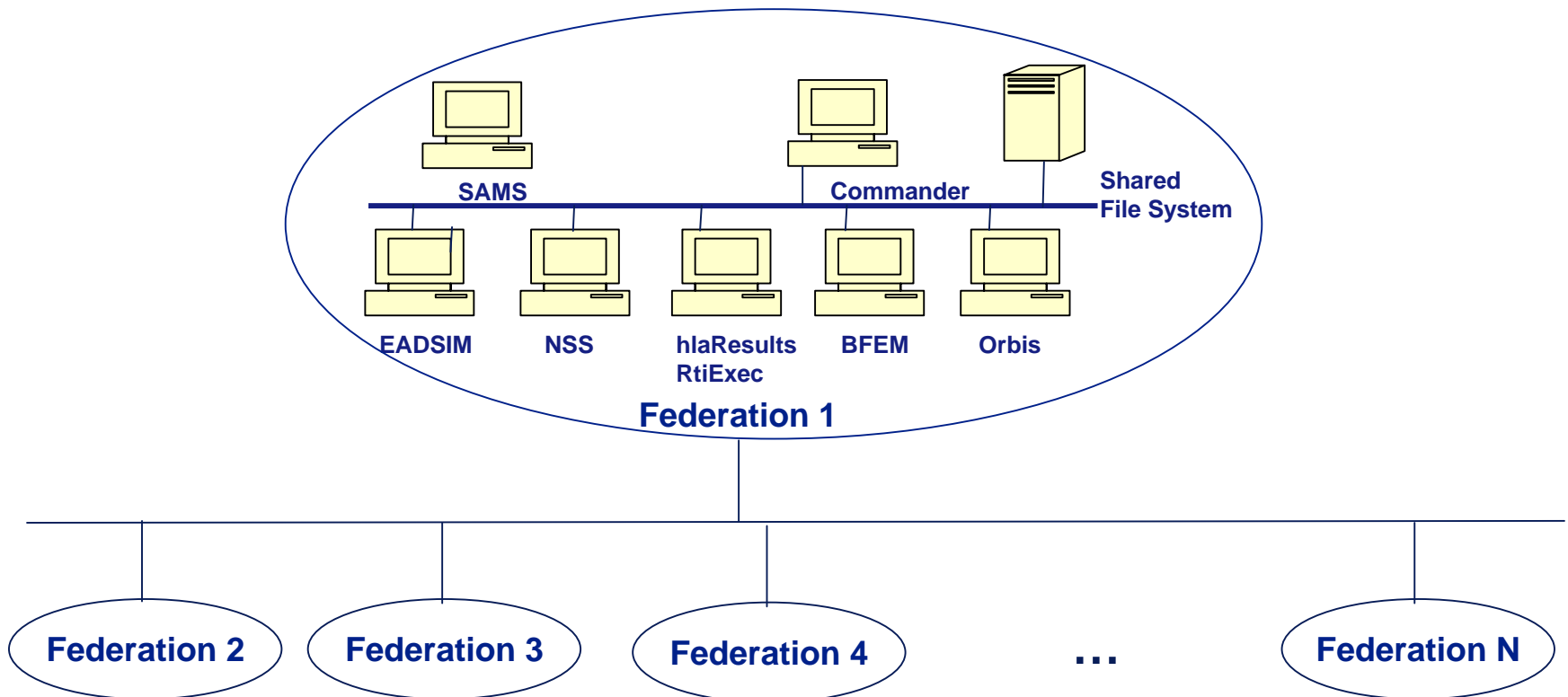
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- **Provide conflict resolution on sensors utilization**
  - **Allocate a sensor system to a warfare area when conflicts arise**

One platform, many sensors and weapons

Control of individual sensors and weapons is implemented by different federates "owning" those objects
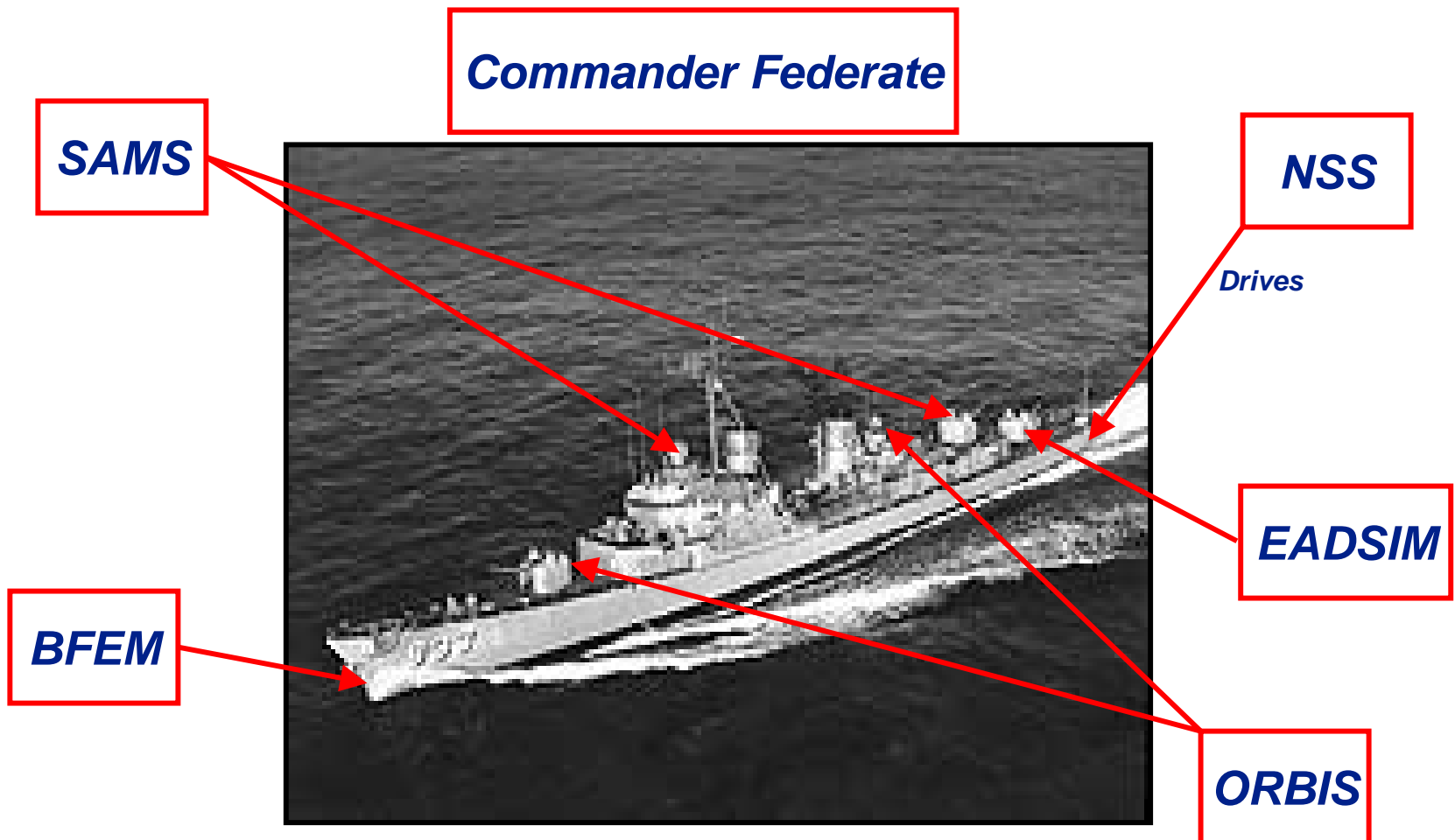
Commander Federate

SAMS

NSS

Drives

EADSIM

BFEM

ORBIS

Agenda

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Summary

- **APL Integrated Multi-warfare Simulation (AIMS) provides a flexible architecture to conduct analysis on the execution of integrated warfare in multiple mission areas**
- **AIMS can add value to multi-warfare analysis**
  - **A Commander Federate, utilizing an expert system, sets warfare priorities either by time or event, and provides inter-warfare area conflict resolution for asset allocation, motion plans, and weapon and sensor allocation among warfare area commanders**
  - **Eliminates sequential, time-consuming data transfers between "stove-piped" single-warfare analysis simulations when conducting multi-warfare studies**
  - **Enhances integrated warfare analysis through selective use of appropriate simulations which have been used in individual warfare area analyses**
  - **Focuses several warfare areas to a common scenario selection across all warfare areas**
  - **Preserves the ability for each model to be used in a stand-alone mode**
  - **Streamlines development of three-dimensional visualization of common OPSITs/TACSITs**
  - **Single Point of Entry reduces duplication of effort and data entry errors by using a single interface for scenario creation**

AIMS Teams (CY05)

- **Requirements for AIMS, SUW, and CDR Federate inputs and rules set (John Benedict, Paul Gulotta, Mike Morris, Ted Smyth, Joe Kovalchik**
- **TACSIT Development (Matt Scarlett)**
- **CDR Federate Development**
  - **Expert inference engine integration (Joe Kovalchik, Jonathan Labin)**
  - **CDR HLA Wrapper (Joe Kovalchik, Jonathan Labin)**
  - **Internal Computations (Joe Kovalchik, Jonathan Labin)**
- **Combat Model internal software modifications**
  - **ORBIS (NSTD, Eric Hu, Dennis Patrone, Todd Warfield)**
  - **SAMS (Kay Stuckey, Ben Kerman)**
  - **BFEM (Ian Craig, Trey Vecera)**
- **HLA Wrapper development for Combat Models**
  - **HLA Wrapper Development for ORBIS (Labin, Kovalchik, Todd Warfield)**
  - **HLA Wrapper Completion/Expansion for SAMS (Chris McDonald, Labin, Kovalchik)**
  - **HLA Wrapper Expansion for BFEM (Labin, McDonald)**
- **RTI Infrastructure (Bruce Miller)**
- **Scenario Implementation**
  - **ORBIS Inputs, Decision Rules for Scenario/Demo (Morris, Emily Stoll)**
  - **SAMS Inputs, Decision Rules for Scenario/Demo (Kay Stuckey)**
  - **BFEM Inputs, Decision Rules for Scenario/Demo (Ian Craig)**
  - **NSS Inputs, Decision Rules for Scenario/Demo (Steve Lange)**
  - **EADSIM Inputs, Decision Rules for Scenario/Demo (Kanaya Chevli, Ken Ryals)**
  - **SPE testing (John Schloman)**

Supporting slides

Form 712A

APL Distributed Scheduler (ADS)

- ## Goal:
  - **Increase number of Federation iterations which can be completed in a given time period**

- ## Approach
  - **Use many network nodes to execute simultaneous Federation executions**
    - **Requires multiple rtiexec instances**
    - **Requires multiple RID files**
    - **Must archive federate results**

APL Distributed Scheduler (ADS)

- ## Technology

  - **Written in C#**

  - **Requires .Net framework 1.1**

  - **Use Windows Management Infrastructure (WMI)**

  - **Windows OS Only**

  - **Uses Domain authentication – user must have rights in order to use a node**

APL Distributed Scheduler (ADS)

- **Network can be crawled to find nodes/resources available to user**

- **Simulation is defined in XML format**
  - **Work: A task (or set of tasks) to be executed on a node**
    - **Prework: copy federate locally**
    - **Work: execute federation**
    - **PostWork: copy results/remove copied files**
    - **May set all relevant environmental variables and paths**

  - **ExecutionEngine:**
    - **Allocates Work to nodes**
    - **Maintains queue of available/used resources**
    - **Will time out Work if desired**

Example Simulation XML File

```xml
<?xml version="1.0" encoding="utf-8"?>
<Simulation xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" NumberofIterations="3">
 <WorkItem WorkName="RTI Executive" CommandLine="\\jwadsim\AIMS\RTI\RTI1.3NG-V6\bin\rtiexec -endpoint %NODE%.scni.jhuapl.edu:%PORT% -multicastDiscoveryEndpoint 224.9.9.9:%MULTICAST_PORT%" WorkingDirectory="\\jwadsim\AIMS\RTI\RTI1.3NG-V6\bin" Priority="0" Sequence="1" Pause="15000" Timeout="600000">
  <EnvironmentVariables>
   <EnvironmentVariables>RTI_BUILD_TYPE=Win2000-VC6</EnvironmentVariables>
   <EnvironmentVariables>RTI_HOME=\\jwadsim\AIMS\RTI\RTI1.3NG-V6</EnvironmentVariables>
   <EnvironmentVariables>SystemRoot=%SYSTEM_ROOT%</EnvironmentVariables>
   <EnvironmentVariables>Path=%SYSTEM_ROOT%;%SYSTEM_DIRECTORY%;\\jwadsim\AIMS\RTI\RTI1.3NG-V6\bin;\\jwadsim\AIMS\RTI\RTI1.3NG-V6\lib;.</EnvironmentVariables>
  </EnvironmentVariables>
  <PreWork>
   <PreWork WorkName="RID Maker" CommandLine="\\jwadsim\AIMS\Scheduler\RIDMaker %NODE% \\jwadsim\AIMS\Scheduler\%RID_FILE% %PORT% %MULTICAST_PORT%" WorkingDirectory="\\jwadsim\AIMS\Scheduler" Priority="0" Sequence="1" Pause="5000" Timeout="0">
    <PreWork />
    <PostWork />
   </PreWork>
  </PreWork>
  <PostWork />
 </WorkItem>
```

Scenario Breakdown Structure for Single Point of Entry

LEGEND

- Implemented in first version.
- Partial implementation / more features in revisions.
- No implementation / to be implemented in later revisions.

METADATA

SCENARIO
Title, date, time-step, local start, local end, …

COMPONENTS

ORGANIZATION
Alliance (Red, Blue), Hostile to, Allied with, …

COMMAND
Commander Type, Location

ASSET
Military ID, category (aircraft, ship...), classification, FOM, publisher, subscriber, …

HLA
FED, FOM, Federate names, versions, random seeds, …

ENVIRONMENT
Cloud cover, sea state, DTED regions, coordinate units distance units, …

BEHAVIORS

PLANS

EMCON
Item, Type, Schedule

LOGISTICS
Supply item, Replenishment station, …

MOTION PLANS
Type (fixed, autonomous), waypoints/bounds (speed, time, course), …

NETWORKS
Network type (duplex, landline), participants, protocol, baud rate, …

TACTICS
Conditions, criteria, Location, response, …

Ground (N)	Base (PS)	
	Entity (S)	
Air (N)	Missile (PS)	
	RotaryWing (PS)	
	FixedWing (S)	Collector (PS)
		Strike (PS)
Sea (PS)	Carrier (PS)	
	SurfaceCombatant (PS)	
	Submarine (PS)	
System (PS)	SensorSystem (PS)	
	WeaponSystem (PS)	
	PropulsionSystem (PS)	

Federation (IR)	Shutdown (IR)	
EngagementReport (IR)	DamageAssessment (IR)	
ContactReportBgOnly (IR)		
ContactReport (IR)		
ReadinessReport (IR)		
ReadinessReportRequest (IR)		
WeaponHit (IR)		
CDROrder		
RequestWithrawal		
Request (IR)		
	ManeuverRequest (IR)	CourseSpeedRequest (IR)
		AreaManeuverRequest (IR)
		IndepOpsRequest
	AssetRequest (IR)	
Grant (IR)	AssetGrant (IR)	
	ManeuverGrant (IR)	AreaManeuverGrant (IR)
		CourseSpeedGrant (IR)
		IndepOpsRequest
WeaponLaunch	Surface_Surface	